Watershed-Scale Ecohydrological Dynamics in the Santa Rita Experimental Range

Nicole A. Pierini[1] , Ryan C. Templeton[1], Agustin Robles-Morua[2], and Enrique R. Vivoni[1,2]

[1] School of Sustainable Engineering and the Built Environment, [2]School of Earth and Space Exploration, Arizona State University

Research Insights in Semiarid Ecosystems, Tucson, Arizona, October 29, 2011

I. Abstract

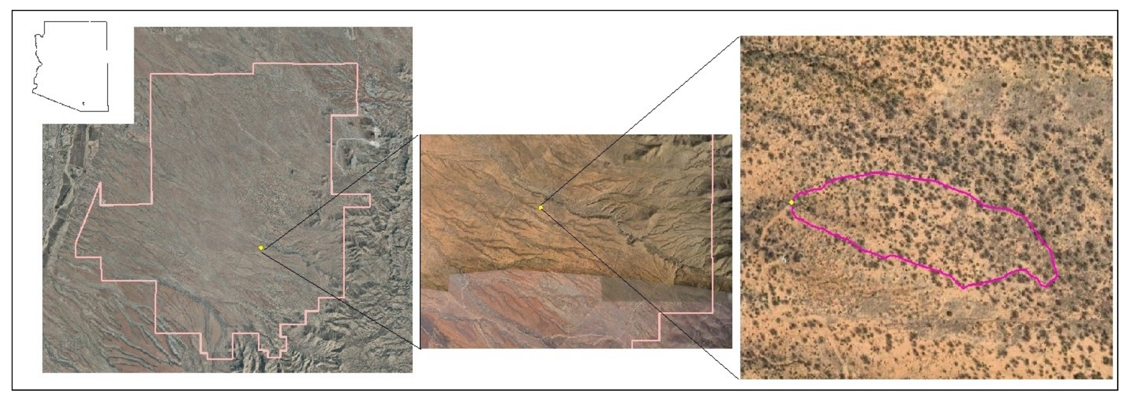
In this study, we present observational activities conducted in a small watershed located in the Santa Rita Experimental Range. We deployed a high-resolution environmental sensor network consisting of 6 rain gauges, 21 soil moisture and temperature profiles, 4 channel runoff flumes and an eddy covariance tower with a complete set of radiation, energy, carbon and water fluxes. In addition, a high-resolution digital terrain model was obtained from LiDAR measurements and a field dGPS survey, allowing characterization of the watershed terrain and plant cover distributions. Using the network, we present preliminary data of the temporal and spatial distributions of rainfall, soil moisture and temperature in the watershed during the summer 2011. The field observations will later be used for one-dimensional simulations of the TIN-based Real-time Integrated Basin Simulator (tRIBS) designed to explore the influence of the vegetation shifts on the landscape dynamics, as in Vivoni et al. (2010). Ultimately, applications of the distributed model in the desert basin will allow us to gain insight on the impact of shifting vegetation patterns on the watershed-scale runoff patterns and explore implications on the site geomorphology.

Research Objectives:

- Improve understanding of seasonality of changes in vegetation properties and the effects on water, energy, and carbon fluxes in a woody savanna
- Analyze seasonality of soil moisture and runoff generation in a first-order watershed at the Santa Rita Experimental Range
- Develop spatially-distributed characterization fields for use in a numerical modeling exercise

II. Study Site Location

The study watershed is located in the Santa Rita Experimental Range in southern Arizona on the western slopes of the Santa Rita mountains in the Sonoran desert. It is a semiarid grassland experiencing woody plant encroachment.



The basin has an area of approximately 1.1 hectares with a mean elevation of 1,161 m. The average slope is approximately 4.2% from east to west. The average annual rainfall at this location is approximately 458 mm between 1975 and 2008 (*Polyakov et al.,* 2010). The photographs below illustrate two major instrument packages: an eddy covariance tower and a channel flume.

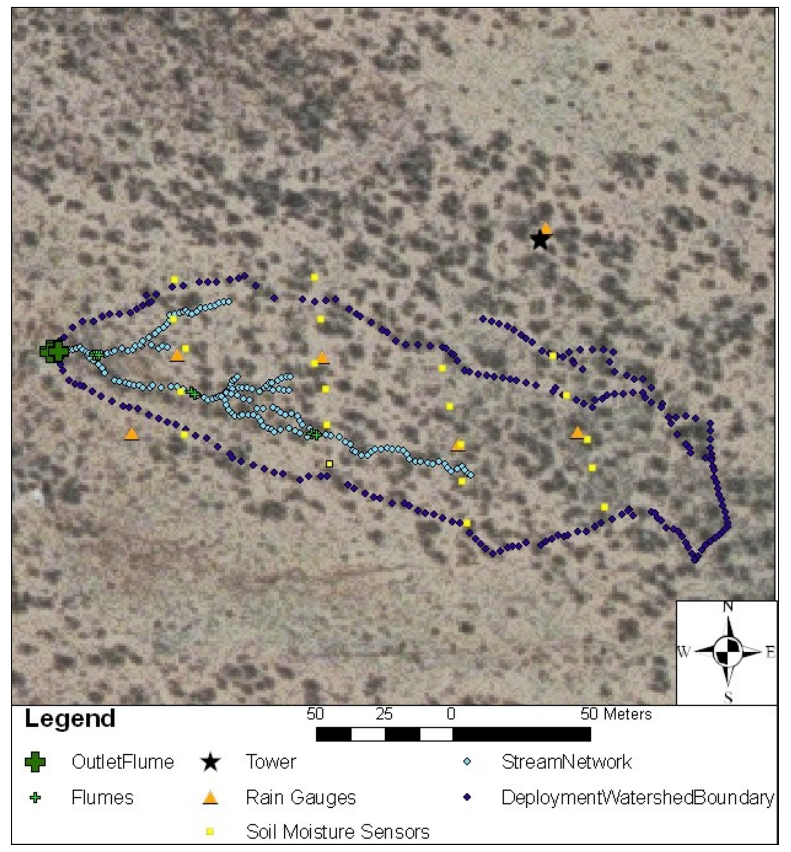
Eddy covariance tower setup

Channel runoff flume within the watershed

III. Environmental Sensor Network

(A) Field dGPS Survey

A field differential global positioning (dGPS) survey was taken in May 2011 to identify an approximate boundary of the watershed and the stream network locations within the watershed. A total of 277 dGPS points were taken at a resolution around 1 meter. The map below shows a representation of the dGPS survey in the study basin.



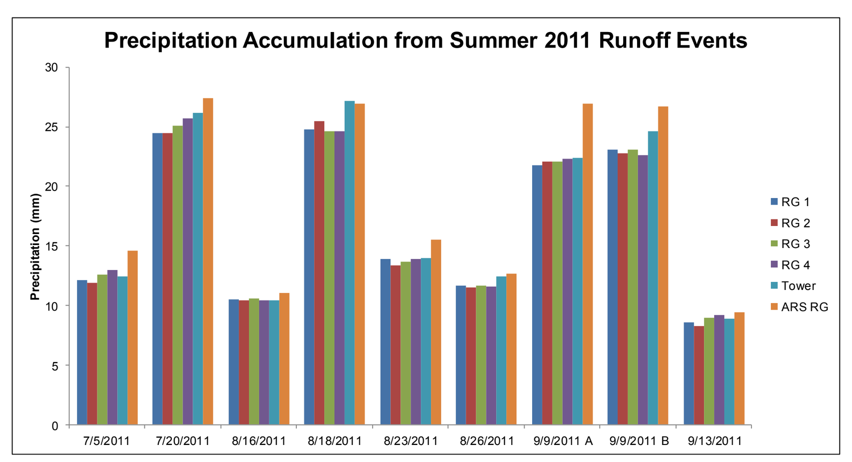
(B) Sensor Network Components

Field Sensors Include:

- 1 Eddy Covariance Tower (including IRGA, sonic anemometer, net radiometer, etc.)
- 4 Channel Flumes (with field calibrated pressure transducers)
- 6 Rain Gauges (static and dynamically calibrated tipping-bucket type)
- 4 Transects with Soil Moisture and Temperature Measurements
- 5 sampling sites on 4 transects at 3 depths (5, 15, and 30 cm) at each site.

IV. Initial Findings for Summer 2011

(A) Rainfall Events During North American Monsoon

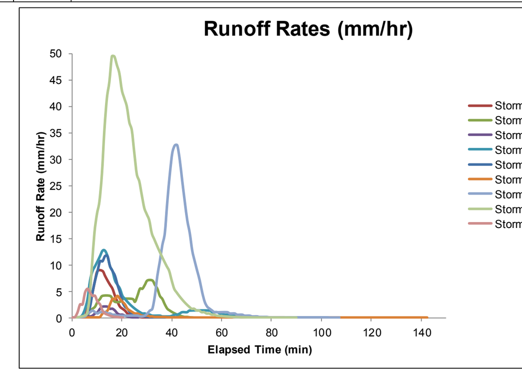


Nine significant storm events that produced runoff from the watershed at the outlet flume are identified for the 2011 Summer season. The associated precipitation events were recorded at the 6 rain gauges and accumulations are shown in the figure above. Spatially variable precipitation was observed as each rain gauge has slightly different values. Rainfall data allow investigation of hydrological forcing to the basin.

(B) Runoff Events During North American Monsoon

Runoff characteristics are evaluated, as in Lane et al. (1978), for the nine significant storm events that produced runoff from the watershed. The table below summarizes these characteristics while the figure below gives the hydrograph for each of the nine storm events.

Storm Number	Date	Runoff Hydrograph					Runoff Ratio
		Start Time	Duration (min)	Volume (mm)	Peak Flow (mm/hr)	Time to Peak (min)	
1	7.5.11	14:39	38.25	1.4	8.816	10.25	0.095858
2	7.20.11	*17:37*	48.5	2.2	7.020	30.25	0.080198
3	8.16.11	13:34	26.5	0.3	2.058	12.25	0.027152
4	8.18.11	14:58	75.5	2.95	12.657	12.25	0.109568
5	8.23.11	17:19	40.25	1.94	11.634	13.25	0.125210
6	8.26.11	19:04	142.5	0.61	4.109	18.25	0.048031
7	9.9.11	17:57	108.25	6.568	32.601	41.25	0.243946
8	9.9.11	~20:01	108	15.419	49.445	13.25	0.578140
9	9.13.11	19:48	20.5	0.64	5.456	6.25	0.068100



The two largest events occurred on September 9th. Runoff ratios varied from about 0.02 to 0.12, except for the two large events where very high runoff ratios were observed, 0.24 and 0.58. Pressure transducer data for each of the three internal flumes has been collected and the runoff responses at each, representing a different area within the watershed, will be evaluated.

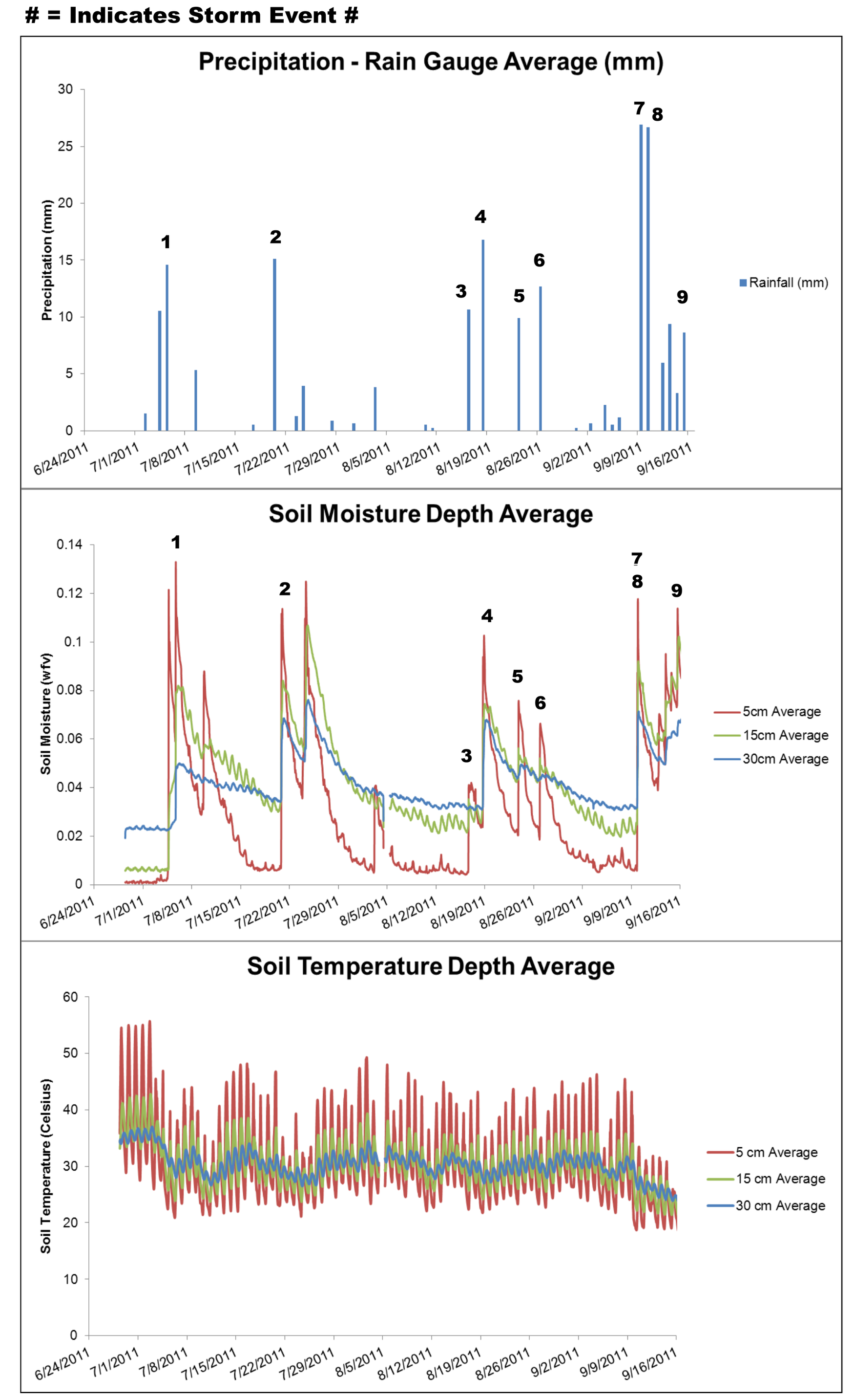
(C) Soil Moisture and Soil Temperature Variability

Soil moisture and soil temperature in the watershed are averaged at the 21 different site locations at the 3 different depths (5 cm, 15 cm, and 30 cm) and shown in the figures to the right. The nine Summer 2011 storm events are identified.

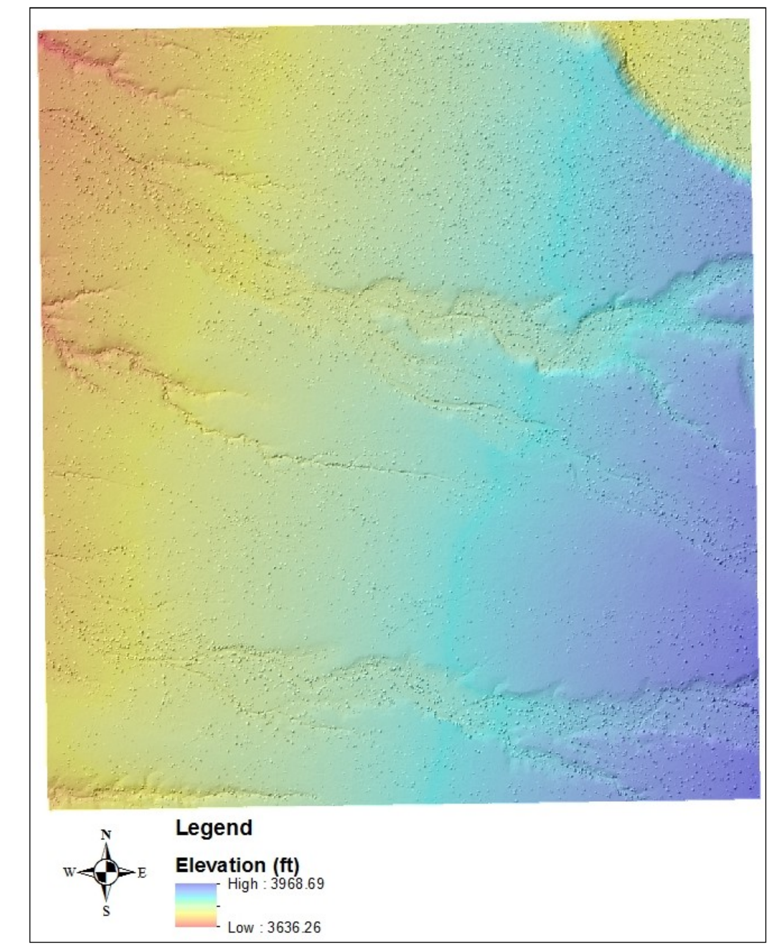
- Soil moisture readily responds to precipitation pulses.
- 5 cm depth is more sensitive to storm events as there are more peaks.
- 5 cm depth shows the highest variability, with the highest and lowest values of the three sensors.
- 15 and 30 cm sensor depths retain more moisture for longer periods of time.
- 30 cm depth is the least variable and really only responds to 6 storm events during this summer period .
- Soil temperature shows a diurnal pattern at all three soil sensor depths.
- Similar to the soil moisture, the 5 cm depth sensor gives the highest variability for soil temperature while the 30 cm depth sensor has the lowest variability.

The 21 different site locations represent various vegetation types and characteristics in the basin, such as bare ground, grassy, under/near mesquite, and near a defined channel. In the future, soil moisture variation with respect to vegetation type and location within the basin will be analyzed.

\# = Indicates Storm Event #



V. LiDAR Analysis



Light Detection and Ranging (LiDAR) data was collected over the study basin and nearby areas in April 2011. The figure above shows part of the collection area and the high resolution elevation data obtained. The LiDAR data along with the high resolution orthophotos will allow vegetation to be characterized within the basin. The fine elevation data will allow the minor changes in aspect, slope, and curvature to be represented. This will be invaluable in defining channels and hillslopes within the basin.

VI. Conclusions and Future Work

This presentation shows the high resolution sensor network setup in a small semiarid watershed and the importance of its measurements to help describe the spatiotemporal variability in the soil, vegetation, and hydrology of the area. The dGPS field survey can assist the LiDAR measurements in defining terrain and plant cover to better characterize the system. The spatially distributed soil sensor network, rain gauges, and channel flumes will be used with high temporal meteorological measurements to build one-dimensional simulations of the watershed response. Future work includes:

- Evaluating the use of eddy covariance for estimating evapotranspiraton (Scott, et al. 2010)
- Exploring relations between soil moisture and temperature with the latent and sensible heat fluxes
- Storm event scale analysis of water, energy, and carbon fluxes

References

1. Polyakov, V.O., Nearing, M.A., Nichols, M.H., Scott, R.L., Stone, J.J, and McClaran, M.P. 2010. Long-term runoff and sediment yields from small semiarid watersheds in southern Arizona. *Water Resources Research*, 46, W09512.
2. Scott, R.L. 2010. Using watershed water balance to evaluate the accuracy of eddy covariance evaporation measurements for three semiarid ecosystems. *Agricultural and Forest Meteorology*, 150, 219-225.
3. Lane, L.J., Diskin M.H., Wallace D.E., and Dixon R.M. 1978. Partial area response on small semiarid watersheds. *Journal of the American Water Resources Assocation*, 14, 1143-1158.
4. Vivoni, E.R., Rodriguez, J.C., Watts, C.J. 2010. On the spatiotemporal variability of soil moisture and evapotranspiration in a mountainous basin within the North America monsoon region, *Water Resources Research*, 46, W02509.